Developing an Air Quality Forecasting Program

- Key elements of forecasting programs
- Forecast audience
- Resources needed to get the job done
- Developing air quality forecast tools
- Verification

Key Elements – Getting Started (1 of 2)

- In the beginning:
  - Identify your organization's commitment
  - Evaluate resources: budget, manpower, and time availability
  - Identify forecast target audience and their needs
- Define a goal for the forecasting program
  - Health-based notification
  - Voluntary action days
  - Mandatory emissions abatement measures
- Consider these issues
  - Size of forecast domain
  - Population affected
  - Pollutants to forecast
  - Industries to be controlled
  - Smog transport

Key Elements – Getting Started (2 of 2)

- Define resources
  - In-house staff
  - Contractors
  - Infrastructure
- Set realistic forecasting goals
  - Public outreach is #1
  - Consistent, reliable product
    - Don't expect to be correct all of the time
    - Perception counts (e.g., visibility reductions)
  - Set reasonable forecast accuracy goals

Key Elements – Program Sophistication

- Basic programs
  - Climatology and persistence
  - Warn public of poor air quality
- Mid-range programs
  - Use of an objective method (i.e., regression) combined with persistence or climatology
  - Use of meteorological forecast data
  - Invoke action days
  - Make agricultural/wildland burning decisions
  - May require interagency coordination
- High-end programs (like Mid-range except)
  - Use of multiple forecasting methods
  - May incorporate rule-defined emissions abatement actions with compliance

Key Elements – Forecasting Timeline

- Daily vs. weekdays with extended weekend forecast
- Seasonal
  - Spring/summer ozone (6 months)
  - Winter CO and NO_2 (3-4 months)
- Year-round PM_{10} & $PM_{2.5}$
  - Spring: windblown dust
  - Summer/fall: photochemical particulates
  - Fall: forest fires and agricultural burning
  - Winter: wood smoke

Forecast Audience

- Internal: identify the chain of communication
  - Air Pollution Control Officer (forecast is made in their name)
  - Air quality outreach (public information, media links)
  - Information management (communication network– fax, internet, telemetry, etc.)
  - Compliance personnel
- External: target to forecast audiences
  - Public through AQI & action day notices
  - Schools & day care (outdoor programs)
  - Cities & hospitals
  - Industry (for emissions abatement actions)
  - Media (the longest weather segment on TV is less than 3 minutes – air quality is a sound-bite)

Forecast Audience – Message Formats

- Forecast messages are typically split by level of user understanding and desired response
- Routine message (Daily Forecast)
  - Consistent format in appearance
  - Consistent content (the message can be repeated)
  - Standardized time of issuance (e.g., 11:00 a.m. daily)
- Special messages (Departure from routine)
  - Urgent forecast update/alert imminent
  - Smoke statement/wildland fires or wood smoke
  - Fumigation
  - Dust storms

Forecast Audience – Message Content

- Dependent on target audience
- Key elements for schools and the public
  - Identify pollutant
  - Identify locations impacted
  - Forecasted air quality category/alert level
  - Forecasted AQI
  - Duration of impact (beginning & end time)
  - Recommended actions to be taken
- Industry – actions to be implemented (yes or no)
- Media – keep it simple, just AQI category

Forecast Audience – General Forecast

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
DAILY AIR QUALITY FORECAST
VALID: WED., FEB. 2, 2000

SRA NUMBER	AREA	1-HR OZONE PPM	8-HR OZONE PPM	8-HR CO PPM	24-HR PM10 UG/M3	24-HR PM2.5 UG/M3	24-HR NO2 PPM	MAX AQI
Los Angeles County: South Coast Air Basin								
1	Central LA Co	.03	.02	4.5	54	37	.09	93
2	NW Coastal LA	.05	.04	6.9	53	36	.09	91
3	SW Coastal LA	.04	.03	13.1	52	36	.08	165
4	S Coastal LA	.04	.03	5.1	52	36	.07	91
5	Southeast LA Co	.04	.03	3.8	60	39	.07	97
6	W San Fernando Vly	.05	.04	4.2	44	32	.05	83
7	E San Fernando Vly	.01	.01	7.9	44	32	.10	100
8	W San Gabriel Vly	.03	.02	4.6	51	25	.06	69
9-1	E San Gabriel Vly-1	.03	.03	3.1	49	23	.04	65
9-2	E San Gabriel Vly-2	.04	.03	4.5	53	26	.05	71
10	Pomona Walnut Vly	.04	.03	3.8	58	28	.09	90
11	S San Gabriel Vly	.05	.04	11.4	38	18	.09	140
12	S Central LA Co	.04	.03	2.1	35	28	.05	75
13	Santa Clarita Vly	.05	.04	2.1	35	17	.02	53
15	San Gabriel Mts	.04	.03	3.0	49	23	.06	65

Forecast Audience – Focused Forecast (1 of 2)

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
SMOG EPISODE NOTIFICATION
FRIDAY, JANUARY 24, 2003

Today's Air Quality: Valid Friday, January 24, 2003
Today, January 24, 2003, air quality is expected to be GOOD to MODERATE in most areas, but air pollution levels will exceed the Federal Clean Air Standard of 100 on the Air Quality Index (AQI) in the following areas:

Area #	Monitoring Area	Description	Pollutant	AQI	Time
23	Metropolitan Riverside	Unhealthful	Ozone	113	2 to 5 p.m.
34	Central San Bernardino Vly.	Unhealthful	Ozone	113	2 to 5 p.m.
35	East San Bernardino Valley	Unhealthful	Ozone	113	2 to 5 p.m.
37	Central San Bernardino Mtns.	Unhealthful	Ozone	113	3 to 6 p.m.

Tomorrow's Forecast: Valid Friday, January 17, 2003
Tomorrow, January 17, 2003, air quality is predicted to be GOOD to MODERATE in most areas, but air pollution levels will exceed the Federal Clean Air Standard of 100 on the Air Quality Index (PSI) in the following areas:

Area #	Monitoring Area	Description	Pollutant	AQI	Time
34	Central San Bernardino Vly.	Unhealthful	Ozone	113	2 to 5 p.m.
35	East San Bernardino Valley	Unhealthful	Ozone	113	2 to 5 p.m.

Forecast Audience – Focused Forecast (2 of 2)

What To Do When Air Pollution Exceeds the Federal Clean Air Standard

In areas with **UNHEALTHY-SENSITIVE** (AQI of 101 to 150) air quality, sensitive or susceptible persons, such as those with heart or lung disease, should minimize outdoor activity.

In areas with **UNHEALTHY** (AQI of 151 to 200) air quality or an **Ozone HEALTH ADVISORY Alert** (AQI of 151 to 200 for ozone), everyone should discontinue prolonged, vigorous outdoor exercise lasting longer than one hour. Examples of the kinds of outdoor activities that should be avoided are calisthenics, basketball, running, soccer, football, tennis, swimming laps, and water polo. Susceptible persons, such as those with heart or lung disease, should avoid outdoor activity entirely.

In areas with **VERY UNHEALTHY** (AQI of 201 or above) air quality or an **Ozone STAGE-1 Alert** (AQI of 201 or above for ozone), everyone should discontinue all vigorous outdoor activities regardless of duration.

Forecast Audience – Media Summary

Area	AQI	Category	Pollutant
Coastal	45	Good	Carbon Monoxide
Metropolitan	75	Moderate	Nitrogen Dioxide
Inland Valleys	125	Unhealthy-Sensitive	Ozone
Low Desert	105	Unhealthy-Sensitive	PM_{10} and $PM_{2.5}$

Resources – Staffing

- Getting started (problem dependent)
  - 2 staff members
  - ½ to 1 day forecaster time commitment
- Mature program
  - 2-3 staff members
  - ¼ to ½ day forecaster time commitment
- Other internal staff
  - Monitoring & telemetry (full-time operations but variable degree of commitment)
  - Outreach & communications, ¼ to ½ person per day

Resources – Daily Operational Manpower Requirements

Task	Time (Hrs)
Analyze air quality and weather	½ - 3
Run forecast model and evaluate	¼ - 1
Disseminate AQI forecast	¼ - 2
Observe developing air quality and prepare for next-day's forecast	½ - 2

Resources – Infrastructure

- Old Days
  - Teletype machines (NWS data services)
  - Wet paper facsimile
  - Telephones
  - Radio broadcast
  - Special monitoring (sounding program)
- Today
  - Internet (data/maps/NWS products/AIRNow)
  - Contracted weather vendors
  - Auxiliary monitoring (e.g., Doppler radar, etc.)

Resources – External Communications

- Web site to host forecasts
- Automated voice recording capability
- Links to other agencies
  - Remote data transfer (AIRNow/state agencies)
  - Post forecast to electronic mailboxes
- Media outreach porthole
  - Special message formats
  - Access to selected host computers

Developing Forecast Tools – What's Good For My Application?

- Start simple and build over time
- Goal to establish reliable product (it's not necessary to be totally accurate)
- Assess weekday/weekend effect
- Persistence-based forecast is easiest to implement and will satisfy many applications
- Persistence, time series, and climatology will never identify a significant change in air quality
- Analog point systems, regression, neural networks, and pattern recognition require time to develop and validate but are usually more accurate than persistence

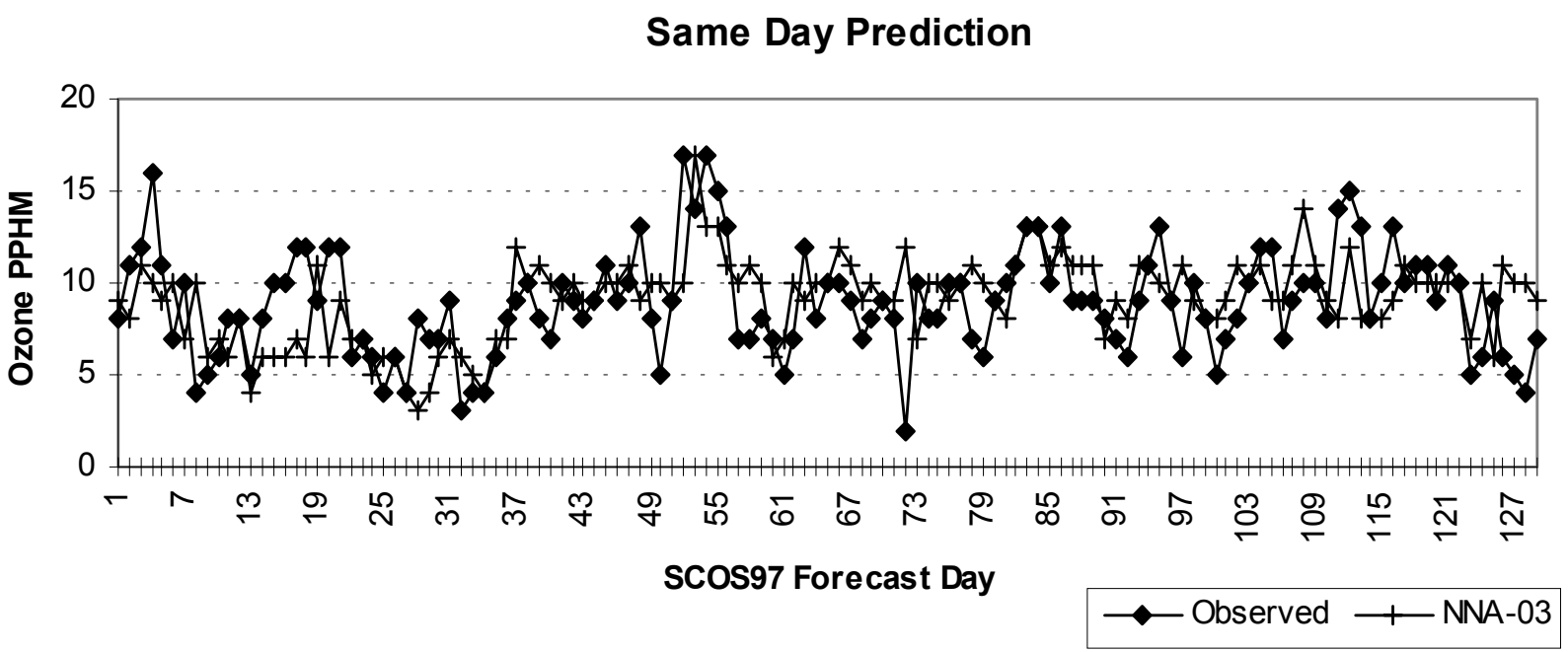
Developing Forecast Tools – General Process (1 of 2)

- Develop understanding by reviewing past episodes
  - Large-scale weather patterns
  - Transport
  - Special local phenomena (emissions anomalies)
- Develop prediction database
  - Meteorological data
  - Air quality data
  - Ideally 3-5 years of data (more data may bridge trend, less data may be insufficient for analysis)
  - Sort data for independent validation and quality assurance

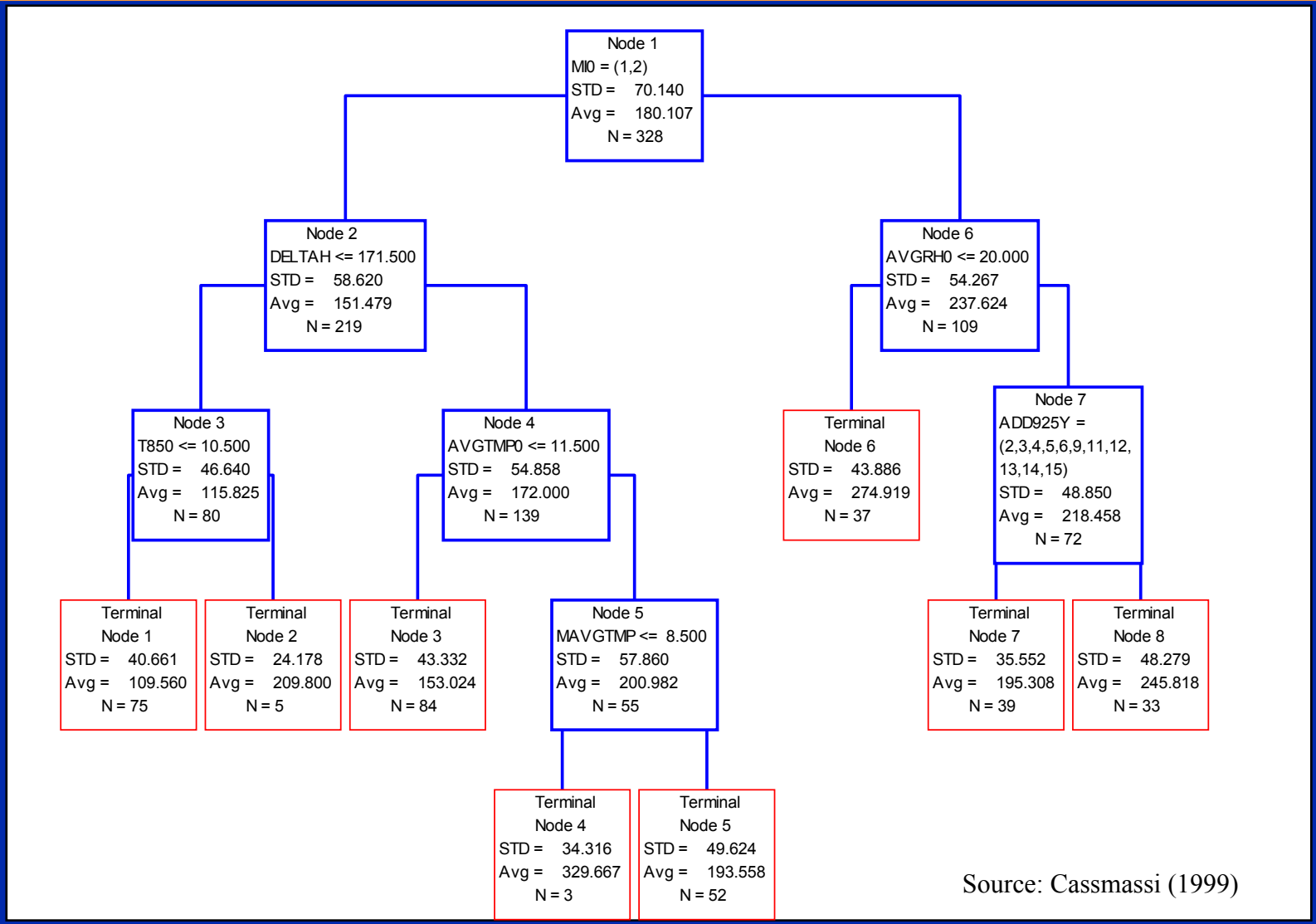
Developing Forecast Tools – General Process (2 of 2)

- Design a model that fits your forecast profile
  - Consider your infrastructure
  - Consider your forecasters
- Start with same-day algorithms
  - Reinforce understanding of past episodes
  - Use direct meteorological predictions to extend to next-day forecasts
- Build day-in-advance algorithms
  - There is no set blueprint – use all reasonable and understandable methodologies
  - Link to available prognostic products (NWS model output, MOS, MM5, etc.)

Developing Forecast Tools – Regression

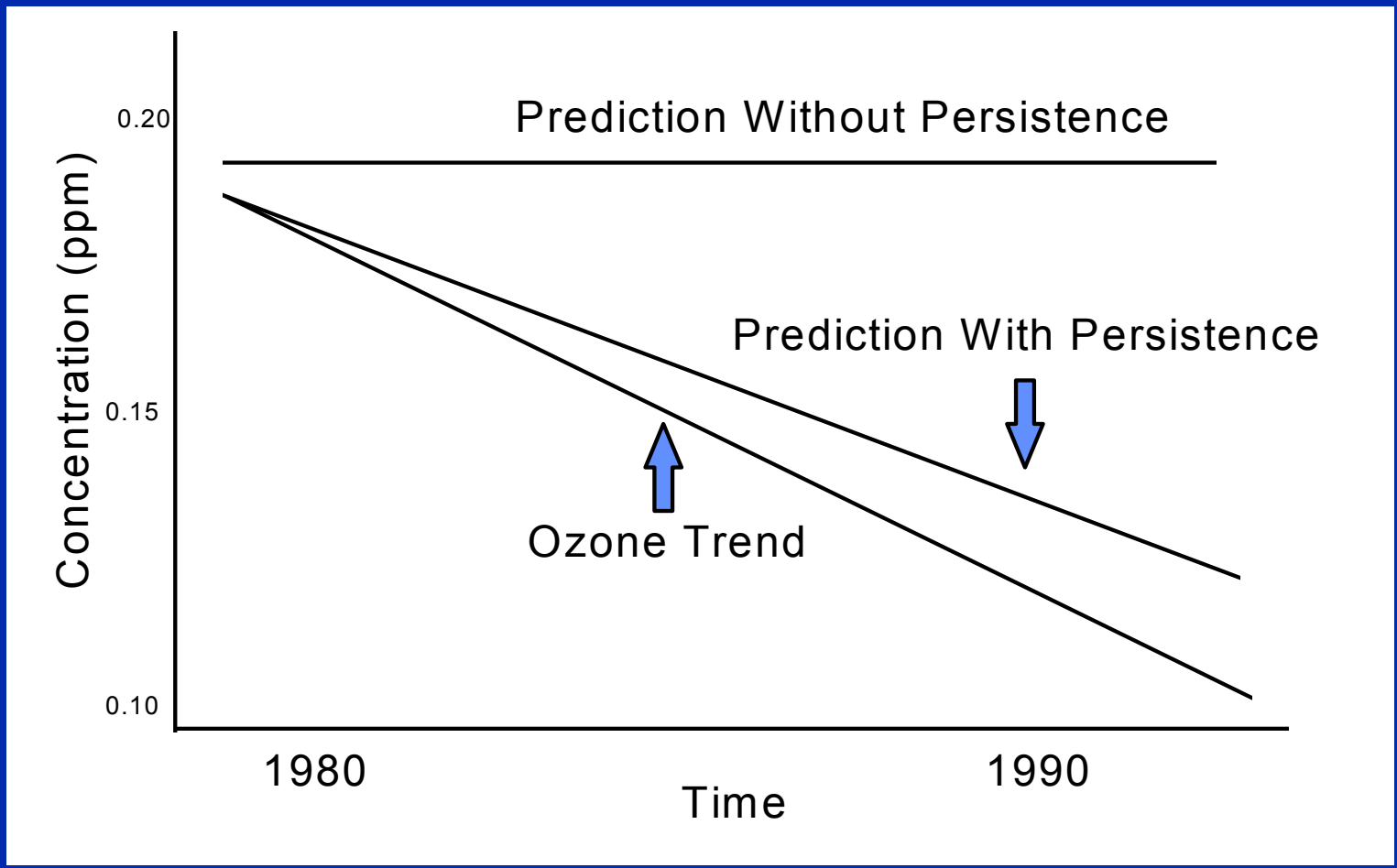


Developing Forecast Tools – Pattern Recognition



Source: Cassmassi (1999)

Developing Forecast Tools – Persistence and AQ Trends



Developing Forecast Tools – Data Considerations

- Develop the forecast tool using data that are routinely available
- Establish data communications protocol
  - Identify and set Internet links
  - Use data vendors
- Develop monthly meteorological climatology for backup
- Note that monitored air quality data don't need extensive Q/A for daily forecasting

Developing Forecast Tools – Importance of Forecast Data

Variable	PM	Ozone	CO
Inversion Strength	High	High	High
Temperature	Medium	High	High
Humidity	High	Medium	Low
Heights Aloft	Medium	High	Medium
Cloud Cover	Low	High	Medium
Wind Speed	High	Medium	High
Persistence	High	High	High

Verification

- You are typically as good as your last forecast!
- Daily verification
  - Can identify systematic problems
  - Can identify mistaken analysis of events
  - Can identify problems with data
  - Provides opportunity for mid-season procedure corrections
- Seasonal verification
  - Identifies if model/methodology is appropriate
  - Benchmarks performance of models and forecasters
  - Is a tool for evaluating emissions trends

Verification – Techniques

- Categorical: Compare observed and forecasted categories (AQI, Ozone Action Day, etc.)
  - Percent correct (PC) - Percent of forecasts that correctly predicted the categories
  - False alarm (FA) - Percent of times a forecast of the category did not actually occur (“crying wolf”)
  - Probability of detection (POD) - Percent of target category days correctly predicted
- Discrete: Compare observed and forecasted concentrations
  - Accuracy - Average closeness between the forecasted and observed concentrations
  - Average Absolute Error - Average absolute closeness between the forecasted and observed concentrations
  - Bias - Indicates, on average, the tendency to over or underpredict the concentrations
- See full discussion in the Ozone and $PM_{2.5}$ Forecasting Guidance Document (U.S. Environmental Protection Agency, 2003).

Verification – Contingency Matrix

		Observed			
		Good	**Moderate**	**Unhealthy for SG**	**Unhealthy**
Predicted	**Good**	n1	n2	n3	n4
	Moderate	n5	n6	n7	n8
	Unhealthy for SG	n9	n10	n11	n12
	Unhealthy	n13	n14	n15	n16

$$\text{Accuracy} = 100 * \frac{(n11 + n12 + n15 + n16)}{(n3 + n4 + n7 + n8 + n9 + n10 + n11 + n12 + n13 + n14 + n15 + n16)}$$

Verification – Acceptable Error

- Forecast should be unbiased - equal numbers of over and underpredictions
- Occasional big misses are expected
  - Review for cause of error
  - Timing may be the limiting factor
- Repeated bias in one direction (high or low) suggests a systematic problem
- Agency policy may impact the bias
- Forecaster error should be differentiated from prediction model error

Verification – Performance Targets

- The average absolute error should be approximately 10% of the maximum observed concentration
- Percent Correct is threshold dependent
  - Start with 50% - 67%
  - Optimally 80% - 90%
- Probability of Detection: 60% - 70%
- False Alarm: 30% - 40%
- The statistics may be misleading if the threshold is set too high or too low - high score
- Changes in forecast performance suggest changes in the air quality trend and it may be time to retool

Summary

Developing an Air Quality Forecasting Program

- Identify your organization's commitment
- Evaluate resources: budget, manpower, and time availability
- Identify forecast target audience
- Develop a message format
- Set realistic forecasting goals
- Start simple and build experience and confidence
- Remember that the forecast is issued daily, and is the agency’s most visible product

- Next steps – Daily Forecast Operations
- Questions